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ASPECTS OF REGIONAL ANALYSIS IN ARCHAEOLOGY

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INTRODUCTION

Regional studies are of growing importance in anthropology. There is a continuing need for expansion of spatial and temporal frameworks for the study of many aspects of human behavior (2, 9). The general acceptance of settlement pattern survey as an archaeological research strategy (111) has created a demand for both new theory and analytical methodology appropriate to regional data. The recent publication of a two-volume work on *Regional Analysis* in anthropology edited by Smith (141) and of a volume on *Spatial Analysis in Archaeology* by Hodder & Orton (65) reflects this demand.

The literature on regional analysis is far more extensive than I could hope to review here. I have, therefore, selected a sharply limited series of topics for more intensive discussion. I will attempt to illustrate the potential importance to archaeological research of concepts developed primarily by geographers, while keeping bald assertions of the utility of various models of spatial behavior to a minimum. This review is organized in three sections of increasing scale of analysis. The first section briefly considers alternative models of human decision-making as the bases of models of spatial behavior. The second section reviews a model of the spatial interaction of groups or populations. The third section considers aspects of the development and operation of regional interaction systems.

BASIC BEHAVIORAL ASSUMPTIONS

All models of spatial behavior ultimately rest on assumptions about the nature of human decision-making. The models reviewed here assume that spatial decisions are made in the context of attempted minimization, maximization, or optimization of certain variables or sets of variables. An assumption of minimization of energy expended in movement, for example, will play a major role in this review. Such

assumptions are both the strength and potential source of weakness of most spatial theory.

The weakness of minimization, maximization, or optimization models is revealed by developments in decision theory. Simon (136) argues that given bounded rationality arising from partial uncertainty (4) and imperfect knowledge, human decision-making is unlikely to conform to minimization, maximization, or optimization models. Decisions are made to satisfy an acceptable but submaximal level of intended achievement.

Although use of this "Simon satisficer criterion" has begun to appear in the archaeological (76, 85) as well as the geographical (53, 178) literature, it has been subjected to some criticism (83, 152, 166). Wolpert (178) favors the satisficer model, but points out in a study of decision-making by Swedish farmers that problems in the determination of the aspiration levels of individuals make verification of a satisficer model very difficult. I might add that even if aspiration levels can be determined, failure to explain those levels reduces behavioral explanation to statements to the effect that people behave in a certain fashion because they wish to do so.

An inability to determine or reasonably assume aspiration levels eliminates the possibility of behavioral prediction by satisficer models. The resulting absence of expected behavior makes comparison with observed behavior and potential behavioral explanation unlikely. The operational strength of minimization, maximization, or optimization models resides in their ability to generate expected behavior patterns. Jochim's (76) use of the satisficer criterion in prediction of a number of parameters of hunter-gatherer resource utilization is illuminating in this regard. He sets aspiration levels for caloric and raw material procurement at those necessary for survival, and generates expected behavior patterns required for survival on the basis of assumptions of effort and risk limitation. His model essentially optimizes the minimization of risk and energy expenditure consistent with baseline survival requirements.

It is useful to generalize an argument by Tiebout (152) to suggest that markedly suboptimal behavior may be inconsistent with the maintenance of an individual, population, or organization within a larger system, and that failure to achieve optimal behavior need not indicate the absence of intent to optimize. Given admittedly bounded rationality, simple optimization models cannot be expected to account fully for observed behavior. Residual variation which is not described by these models should reflect, however, the degree and nature of suboptimal behavior.

I do not advocate the priority of economic maximization in decision-making by members of nonmodern, nonmarket based societies. Social, political, and other considerations are of more than obvious importance in these cases (34). I do feel, however, that without a theoretical baseline against which to compare our data, potential behavioral explanation is precluded, and we are reduced to descriptive exercises. If our models are inadequate, we should improve not abandon them. I note a number of efforts in this direction in the following pages, among the more interesting of which are Isard's (72) and Webber's (166) work on the effects of uncertainty on locational decision-making.

INTERACTION AND DISTANCE

A model that systematically relates the basic variables involved in the interaction of human groups should be of some interest to archaeologists. These variables include the size and nature of the groups engaged in interaction, the nature of that interaction, and the physical space over which that interaction occurs. Plog (114) has recently suggested that "gravity models" might be appropriate for this purpose.

Gravity models are widely used in cultural geography for the description of interpopulation interaction. Here the term population simply refers to defined human groups of varying sizes and compositions, not necessarily to populations in the demographic sense. In their best-known form, gravity models rely on a direct analogy with Newtonian physics and specify that the expected interaction between two populations is a function of the ratio of the product of their sizes to the square of the distance between them (184). Although few studies have found this simple formula to be an accurate interaction predictor, there is an impressive body of evidence that interaction varies inversely with some function of distance and directly with some function of the sizes of interacting populations (23).

Gravity models as a class have been criticized for their lack of theoretical justification (75). Olsson (109) points out, however, that their application to situations involving reflexive or reciprocal interaction has a valid theoretical base. These reflexive interactions involve maintenance of personal contact over distance and are thus subject to movement costs. We may then apply a simple assumption of minimization of energy expended in movement to generate distance decay, or decreasing interaction with increase in the distance over which that interaction takes place. Most social processes likely to be advanced to explain archaeological interaction data are of this type, and include such processes as trade, exchange, and marriage alliance. It is also understandable that interaction should be a partial function of population size. The model simply assumes that the number of people or groups involved in interaction is positively correlated with the number that could be so involved, given population sizes.

Geographers are able to utilize direct measures of interaction in terms of the physical movement of people, goods, services, or information between populations. Isard (71) provides a number of case studies involving the interaction of populations as measured by such variables as number of telephone calls, shipment weight moved by railroad, family migration, numbers of bus passengers and so on, between population centers.

Archaeologists usually lack direct measures of interaction. They typically assume that the similarity of two artifact assemblages, artifact types, etc provides a measure of the degree of interaction between the producers of those assemblages or types (60, 84, 91, 95, 114). This may be the case as long as style is not being used to signal exclusive group membership and maintain social boundaries between the interacting populations (177). In this case the stylistic similarity of artifact types produced by two groups might be low, while the actual group interaction rate is relatively high.

The question of just how to measure similarity is also of interest. A brief review of the literature reveals a variety of techniques in use. These include Brainerd-

Robinson similarity coefficients and linear correlation coefficients (114), Euclidian distance functions (5), factor loadings (7, 127), chi-square values (117), coefficients of homogeneity (169), taxonomic similarity coefficients (91), as well as a variety of other statistical and graphic techniques. While this is not the place to pick and choose among techniques, we should remember that they handle variability in very different ways. It is important that the technique chosen should be relatable to the specific type or types of interactive behavior thought to operate in individual cases [e.g. Whallon (169)].

Most of the techniques listed above assign equal importance (weights) to all variables or attributes involved in a particular analysis. Recent ethnographic studies [e.g. Friedrich (46)] suggest that within individual artifact types, some attributes are sensitive to interactional variability while others are not. The same is no doubt true for artifacts within assemblages. Plog (115) points out that little attention has been given to problems of attribute selection in interaction studies. I might add that systems of reliable attribute or artifact weighting appropriate to specific types of interaction have yet to be developed.

With the exception of rare interaction data from ancient texts (153) or ethnohistoric accounts, one class of more direct interaction data is frequently available to archaeologists. This involves the distribution of goods for which location of production is known. Studies of the distribution of obsidian (39a, 113, 124, 133, 133a, 180), Near Eastern chlorite (87), and various types of European flint (104) are examples of this type. Even here, however, it is difficult to stipulate the type of interaction occurring. Although Renfrew (121, 123) has attempted to differentiate exchange processes on the basis of associated differences in expected artifact distributions, Hodder & Orton (65) argue on the basis of distribution simulations that similar distribution patterns may result from a variety of exchange mechanisms.

Identification of the type of interaction involved in a particular case is even more difficult when the basis of such interaction is considered to be something other than material trade. It would seem that postmarital residence patterns have been the most commonly selected alternative in these cases (35, 60, 98, 169).

Of the three variables employed in gravity models, the first, interaction, remains the most elusive both in identification of its form and its measurement. Consideration of the probable characteristics of interacting populations may, however, partially explicate the type of interaction involved.

The size of interacting populations is the second variable of a gravity model. As mentioned above, the Newtonian analogy specifies the simple product of the population sizes involved as the appropriate value in the gravity equation. Use of this value is not as arbitrary as it might seem. Note that the product of the sizes of two populations is equal to the number of possible one-to-one relationships (without regard to order) of individuals between populations. For example, if population I consists of three individuals (A, B, and C) and population II consists of four individuals (a, b, c, and d), the possible one-to-one relationships between populations are as follows: Aa to Ad, Ba to Bd, and Ca to Cd. There are 12 of these pairs, a number equal to the product of the two population sizes.

Clearly the Newtonian model assumes a maximal interaction situation in which each member of one population interacts with all members of another. Even though

such interaction might be indirect, interaction densities of this magnitude are probably unusual. It should come as no surprise then that geographers usually find it necessary to transform population products to obtain aesthetically pleasing linear relationships between measures of interaction and distance. Most such transformations involve application of a best-fit exponent to the population product (109, 184).

Unfortunately, exponent transformations provide for better description than explanation. More behaviorally interpretable transformations should take a number of issues into consideration. Interaction densities were discussed above. Interaction rates, or the number of interactional events per unit time, should also be considered. High density, low rate interaction might well generate similar interaction intensity values as low density, high rate interaction but have very different behavioral significance.

Although factors of density and rate will be difficult to ascertain archaeologically, a third factor of operational population size should be more approachable. As emphasized by Olsson (109), the population sizes used in a gravity equation should reflect the actual numbers of people involved in interaction. This value is not necessarily equal to that for total population sizes. Failure to recognize subpopulation interaction may severely distort the results of archaeological interaction studies.

Hodder & Orton (65), for example, find that distance has an apparently differential effect on the distribution of a number of different artifact types. They measure the effect of distance by the exponent to which intersite distances must be raised to obtain best-fit linear interaction plots. Interacting population sizes are not considered.

They define two groups of artifacts with similar characteristics. The first includes the rather undistinguished products of local, small-scale production and includes Romano-British roofing tiles, two Romano-British ceramic wares, and two types of neolithic axes. Best-fit distance exponents for this group ranged from 0.1 to 0.6.

The second group of artifacts consists of the rather more distinguished products of large-scale concerns. These include a neolithic axe type, a fine neolithic ceramic ware, neolithic Anatolian obsidian, Iron-Age Dobunnic coins, and two fine Roman ceramic wares. Best-fit distance exponents for this group range from 0.9 to greater than 2.5.

The higher distance exponents for the second group would indicate a higher frictional effect of distance on their distributions, although the range of their distributions is greater than that for items of the first group. Of greater interest, however, are the differences observed between the two groups, which might better be explained in terms of the probable nature of the interacting populations who generated the observed distributions. Briefly, the artifacts involved may have been status related: the first group being one of relatively low status items and the second (including Dobunnic coins) being one of relatively higher status items. Given the observation that social systems usually contain fewer higher than lower status individuals, frequency of higher status related items is expected to be less than that of lower status related items.

Phrased in terms of a gravity model, the sizes of the interacting populations involved in the distribution of Group 1 items were probably larger than those involved in the distribution of Group 2 items. This differential in subpopulation sizes

might be sufficient to account for a significant proportion of the intergroup difference in best-fit distance exponents. This "status hypothesis" would also account for the greater observed distributional range of the probable higher status items if the wealth necessary to defray movement costs over longer distances was associated with higher status individuals.

Subpopulation definition by status group should probably be a relatively common component of archaeological interaction studies. Flannery (40), for example, has suggested that the interaction represented by exchange of Olmec materials was probably among local elites. A similar model of elite exchange has been used to describe the operation of the Middle Woodland "Hopewell Interaction Sphere" (146, 181).

Status, of course, is not the only dimension of social variability that might define interacting subpopulations. Age, sex, wealth, occupation, or other group affiliation might function in a similar way. Kay (84) notes that the relationship of three Central Missouri Hopewell projectile point assemblages in taxonomic space approximates the locational relationships of the three sites from which the assemblages were excavated. He suggests that assemblage similarity provides a measure of interaction among projectile point makers, perhaps males. This might well be restricted to adult males. Similar sex-specific interaction has been an important part of several other archaeological studies (35, 36, 60, 98, 169).

As difficult as definition of appropriate subpopulations may be in the preceding examples, predictable situations may be more complex. Consider the possibility that the subpopulations involved in interaction monitored by the distribution of a given artifact type change over space. A raw material or artifact type might be very abundant in the vicinity of its source and be accessible to entire populations. As the item decreases in availability with distance from its source area, however, the context of its use may become less utilitarian and more social. Use by subpopulations of such items as status markers, exchange regulating symbols, etc should be relatively common in the archaeological record.

The distribution of some neolithic Near Eastern obsidian may conform to such a model. Renfrew (120) provides a semilog plot of (log) percentage of obsidian in lithic assemblages against distance of assemblages from obsidian sources for a series of Near Eastern sites dating between ca 6500 and 5000 B.C. His plots are basically linear except for marked flattening within about 300 kilometers of source areas. Renfrew refers to the areas within which flattening occurs as supply zones.

Although Olsson (109) notes flattening of interaction curves for short distance contacts, the effect seems to occur in modern data only within radii of about 5 kilometers (114). Three hundred kilometers would not seem to qualify as a short distance contact, especially under neolithic transport conditions. Renfrew (123) suggests that this flattening is due to differential interaction rates inside and outside supply zones which he equates with culture areas.

Access to obsidian artifacts appears to have become increasingly associated with high status positions throughout much of greater Mesopotamia, especially from the Halaf period onward (180, 181). The flattening of Renfrew's graphs based on earlier material may be due in part to systematic shifts in the size of interacting populations,

from general populations near source areas to increasingly specific subpopulations away from source areas.

An alternative hypothesis has been presented by Hodder & Orton (65), who have generated similar curves through random-walk simulations which involve a relatively large number of relatively short distance movements or exchanges. Random-walk generated curves also approximate the distribution of an Iron-Age coin series (66). These simulation results suggest that interaction curves like those defined by Renfrew may involve neither differing interaction rates across cultural boundaries nor the sort of shifts in interacting population sizes suggested above. While the random-walk model applied by Hodder & Orton is of considerable interest, I must admit a theoretical preference for approaches that include consideration of specific characteristics of interacting populations.

By now it should be clear that population size is a more complex variable than inspection of a normal gravity equation might indicate. The same observation will be made below for distance, the third variable of the gravity model equation.

While most studies use simple linear distance measures (miles or kilometers) there is no reason to believe that these are appropriate for all cases (56, 109, 114). Various measures of distance should reflect energy expenditure required for travel or transport, that is, the movement costs of interaction (57). The most appropriate distance measure for a specific case would be that most highly correlated with movement costs. In highly developed economies where "time is money," elapsed time as well as movement costs may effect the operational distance between two points.

Geographers may have the data to transform distance directly into movement and/or time costs (55, 156, 173). Archaeologists are seldom so fortunate. We may, however, be able to estimate values for another common distance transformation, travel time. For obvious reasons of topographic variability, energy expended per unit distance moved may vary. If we assume that cost per unit time is relatively constant and that the time required to move a unit distance varies under different conditions, then travel time should be a better estimator of movement costs than linear distance.

A number of archaeological studies have used or suggested travel time transformations (39a, 123a). Hodder (63) and Hodder & Orton (65) show how water transport may have differentially affected interaction as measured by the distribution of Roman pottery produced in Oxford. Rowlett & Pollnac (127) see some correspondence between major topographic features and isoload maps of factors resulting from their analysis of La Tene la cemeteries in the northern Champagne district of France. The following example may better illustrate the potential importance of distance transformation in archaeology.

LeBlanc & Watson (91) have calculated a matrix of similarity coefficients among ceramic decorative motif assemblages from seven Near Eastern Halaf sites of the early fifth millenium B.C. Maximum site-to-site distance is on the order of 600 kilometers.

With the exception of one site (Yunus), LeBlanc & Watson note that interassemblage similarity coefficients are related to intersite distance. Figure 1A shows the relationship between assemblage similarity and linear intersite distance measured on 1:100,000 operational navigation charts. Figure 1B shows the relationship between

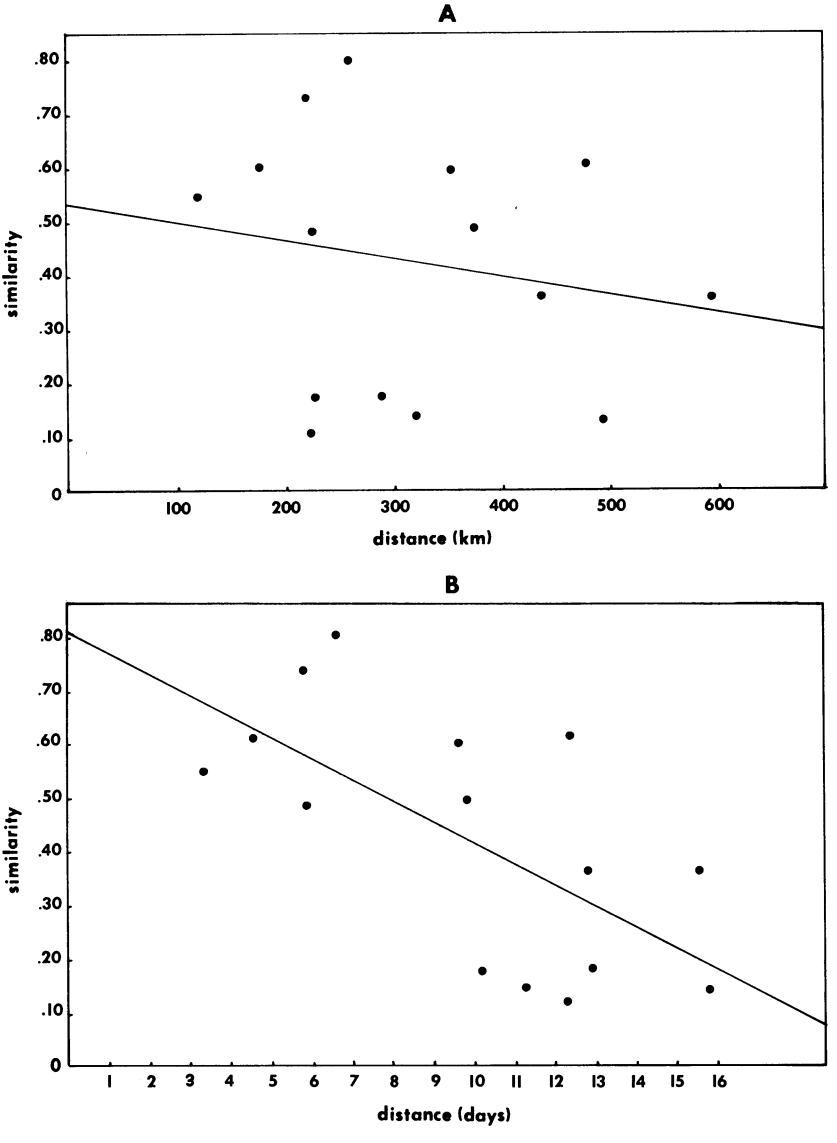

Figure 1a Relationship between stylistic similarity and intervening linear distance among six Halaf ceramic motif assemblages ($n = 15$, ($r = -0.179$, $p > 0.05$).
Figure 1b Relationship between stylistic similarity and travel time transformation of intervening linear distance among six Halaf ceramic motif assemblages ($n = 15$, $r = -0.655$, $p < 0.01$).

assemblage similarity and a travel time transformation of intersite distance suggested by H.T. Wright (personal communication).

This transformation is achieved by partitioning a linear distance into topographic components of flat, hilly, and mountainous terrain and converting these components into estimated travel times. Travel time over a given linear distance of each of these three terrain types was estimated from nineteenth and early twentieth century travel accounts (38, 59, 89, 90, 97, 143). Note that this transformation increases the linear correlation between distance and similarity from –0.179 (p greater than 0.05) to –0.665 (p less than 0.01).

Travel time is not only an efficient distance transformation in this case but also it has a direct behavioral interpretation not shared by transformations which utilize a best-fit exponent of linear distance. The latter approach is very common in economic geography (57, 184) but serves as a descriptive device of little apparent explanatory power.

Unfortunately, appropriate transformations of spatial distance are not the only distance functions that can be expected to affect movement and interaction. Leone (95) and Wilmsen (171, 172) utilize concepts of social distance in archaeological interaction studies. Wilmsen provides an interesting social transformation of spatial distance, suggesting that interaction among hunters and gatherers is inversely proportional to the number of band territory boundaries between two groups. Wobst (175) has successfully used this distance measure in simulations of hunter-gatherer mating networks. Olsson (109) cites studies utilizing concepts of socioeconomic class and age distances to describe certain interactional patterns. Sahlins's (130) discussion of the potential effects of kinship distance, rank, and wealth differences on exchange relationships suggests other possible nonspatial distance measures. Mooney's (105) recent work on the Coast Salish reinforces the view that a variety of nonspatial distance transformations may be necessary to the understanding of certain types of interaction.

I have little doubt that the interaction monitored by measures of attribute, artifact, or assemblage similarity are often conditioned by a combination of spatial and nonspatial distance functions. A concept of operational distance might be useful in emphasizing the potential effects of both types of distance functions on the interaction of populations.

The application of gravity models to archaeological interaction data is a complex issue. If gravity models provide nothing else, they do encourage archaeologists to consider more systematically the variables involved in interaction. This itself would seem to be a valuable service and justify their utilization. More optimistically, if archaeologists are willing to give more consideration to the type of interaction being monitored in particular cases, as well as to attempt behavioral transformations of the population and distance variables, gravity models may have a utility beyond that of elegant description. The explanatory potential of these models may have been underrated, in that they can systematically relate basic variables of interaction to one another and to a general behavioral assumption of movement minimization.

REGIONAL INTERACTION SYSTEMS

Thus far I have considered models of interaction between populations largely localized in permanent settlements of varying sizes. The existence, stability, and size variability of these settlements has been taken for granted. Given the proportion of the archaeological record occupied by mobile hunters and gatherers, sedentarization as well as settlement formation and size differentiation should be examined more carefully (20, 42).

Settlement System Development

A seasonal cycle of mobile hunter-gatherer resource exploitation involves movement among a series of spatially discontinuous resources. The amount of movement involved may be considerable. Wobst (176) uses an estimate of maximal band population size based on earlier simulation studies (175) and ethnographic population density figures from Alaska, Canada, and Siberia to suggest probable territory sizes of between 9,500 and 95,000 square kilometers for prehistoric bands in similar environments. Sedentarization or even significant reduction in required territory size would produce very considerable energy savings through reduction of required movement. I will suggest below that movement minimization is an important factor in both sedentarization and settlement formation.

Pianka (112) suggests on general ecological grounds that exploitation of a "patchy" environment (one characterized by resource heterogeneity and spatially discontinuous resource distributions) involves a series of movement related costs. These include travel time between resource "patches" as well as search and pursuit times within individual patches. (Note that pursuit time includes resource pursuit, capture, and consumption.) He further notes that required travel time is inversely related to patch size and required search time is inversely related to within-patch resource density. Given a movement minimization assumption, populations exploiting environments with larger patch size and/or density should be characterized by less movement than those exploiting environments with lower patch size and/or density.

An additional variable must be added at this point. Lee (92, 93) and Jochim (76) stress that resource reliability as related to risk minimization is an important factor in the determination of patterns of resource utilization. Reduction of movement costs through sedentarization would thus seem to be favored by a number of resource factors including high reliability, density, and large patch size (see also 54a). The relative sedentarization of such ethnographically known hunters and gatherers as the Ainu (162) and various Northwest Coast groups (148) would seem to be explicable in these terms. Similarly, Clark (27) notes that the apparent degree of seasonal movement of prehistoric hunters and gatherers in sub-Saharan Africa was related to environmental "richness."

As Flannery (42) points out, agriculture as a subsistence technique does not imply sedentarization. Agriculture appears to have preceded sedentarization in Mesoamerica, while the reverse seems to have been the case in the Near East (43). It might

be interesting to view floral food production from the perspective of the general ecological variables outlined above.

I suggest that cultivation of a plant type(s) might be viewed as an attempt to achieve one or more of the following goals: 1. decreased travel costs through increase in the patch size of the plant concerned; 2. decreased travel costs through creation of a new plant patch in the immediate vicinity of a sedentary occupation; 3. decreased search costs through increase in within-patch plant density; and 4. Increased resource reliability through intentional cultivation and care of the plant type(s) involved. Given potentially high yields, the importance of agriculture in an overall subsistence strategy is probably most closely related to reliability factors. Lees & Bates (94) argue that productive uncertainty under early dry farming conditions in the Near East would favor mixed subsistence strategies, a situation that is reflected in relevant archaeological data (43, 67). Early agriculture may be viewed in part as an example of a movement and risk minimization subsistence strategy.

Sedentarization, agricultural or otherwise, need not imply the sedentary population agglomeration we associate with "villages." I will have occasion in a later section of this review to refer to the concept of "scale economics" or ". . . the savings in costs of operation made possible by concentrating activities at common locations" (48, p. 305). Garner (48) suggests that similar considerations may account for the agglomeration of activities and people that form settlements themselves.

Movement minimization is the core assumption of scale economics. To the extent that productive activities require the cooperation of population units (individuals, families, etc) agglomeration of those units in a settlement should reduce personnel and material movement costs, as well as information transfer costs required for cooperation.

Settlement location as well as sedentarization and settlement formation appear to be related to movement-minimizing behavior. Transport costs play a central role in von Thünen's (151) early model of agricultural land use, in which distance from a settlement largely determines type of land use within concentric zones around that settlement. Chrisholm (25) argues that type of land use is directly related to labor input to its exploitation, and the amount of such labor is inversely related to distance from settlement. Horvath (68) finds support for this model in his analysis of land use around Addis Ababa, Ethiopia, while Henshall (58) cites studies with similar results of relatively simple agricultural systems in Africa, India, and Brazil.

Minimization of effort required for subsistence activities is often cited as a primary determinant of archaeological settlement location (47, 50) and in conjunction with von Thünen type land use models forms the basis of "site catchment analysis" in archaeology (73, 74, 160).

On the assumption that to minimize movement costs a settlement is located in the center of the resource area which its inhabitants exploit, catchment basin analysis normally defines the radius of that resource area as the distance beyond which energy expended in movement equals or exceeds the energy return of exploitation. Weighting of resource availibility within this radius by distance from a settlement allows definition of a resource mix potentially exploitable from that settlement.

Given a known exploitation pattern, the method may suggest resource determinants of settlement location, or be used to compare the productive potential of an area with the size of the population actually inhabiting it.

A number of interesting applications of catchment basin analysis have recently appeared (24, 28, 39, 126, 185). Of interest here is the general conclusion that in simple systems there is a strong inverse relationship between distance and resource exploitation, a conclusion consistent with the results of distance decay studies cited above.

This observation may be important in accounting for multiple rather than single sedentary population agglomerations within a region. Given low population densities and the factors favoring sedentarization and agglomeration mentioned above, it is not obvious why the population of a region should not agglomerate in a single village.

Sahlins (130) cites a variety of ethnographic studies indicating markedly submaximal levels of subsistence production in relatively simple societies. Similar observations have been made as a result of archaeological catchment basin studies of the sort mentioned above (22; 44, pp. 173–80; 85). Sahlins (130) relates submaximal production to a model of household strategies in which production in excess of subsistence requirements is unnecessary. If we accept a low level of productive intensity (labor input per unit land exploited) for early agricultural societies, then relative intensification of production to accommodate an initially larger rather than smaller village population is unlikely. Larger village size approaching the population size of a low density region could be achieved alternatively by increasing the amount of land exploited at a given intensity. Even with a concentric zone model of resource utilization of the type discussed above, increase in the amount of land exploited would involve increase in energy expended in movement. Multiple village occupation may then be seen in part as a strategy to minimize both required productive intensity and energy expended in movement, consistent with the advantages of population agglomeration.

Few regions, however, can be characterized by a distribution of villages of approximately equivalent sizes. Sources of variability in village size, and particularly processes leading to the development of differentially large villages, are of some interest. If we continue to assume low intensity subsistence production, then differences in resource availability are unlikely to account for differences in village size unless resource disparities are very great indeed.

Wobst (176) has discussed a number of locational relationships for hunter-gatherer settlement systems which may be illuminating for early sedentary agriculturalists as well. His simulation studies suggest that long-term population maintenance requires a minimum size of mating network (roughly homologous with a maximal band) of about 475 people. It seems fair to assume that the size of mating networks for early sedentary agriculturalists was not significantly smaller than this estimate.

Early agricultural villages from a number of areas of the world appear to have been quite small, averaging perhaps 100–150 people. Marcus (101) estimates that as many as 90 percent of early Mesoamerican villages were occupied by 50–60 people. Renfrew (122) suggests a population figure of 100 as typical for villages of

the early Aegean neolithic. Other early village population estimates include 100–300 for Japanese Jomon (163), 100–200 for early East African neolithic (27), and 100–150 for early European Bandkeramik villages (103, 144). It appears that the inhabitants of these early villages were probably involved in supravillage mating networks.

Wobst (176) goes on to point out the importance of the spatial distribution of local bands for the operation of a mating network, as well as conditions under which a given band may have a locational advantage within that network. He specifically suggests that under conditions of mating system closure or full time exploitation of essentially linear environments, a centrally located band has a marked advantage of minimum average distance from other bands in their mating network. Given an inverse relationship between interaction and distance of the sort discussed above in conjunction with gravity models, frequency and/or intensity of interaction with other bands should be directly related to the relative centrality of the location of an individual band. Differential interaction rates may then suggest differential success in mate acquisition, differential reproductive success, and differential band sizes.

The locational implications of centrality in a linear environment should apply to early sedentary agriculturalists as well as to hunter-gatherer populations, given village participation in supravillage mating networks as suggested above. It is interesting, therefore, that San José Mogote is both centrally located and by far the largest settlement in a linear settlement distribution of the late San José phase of the Etla region, Oaxaca (44, pp. 173–80). A similar though less impressive case can be made for Period VI settlement of the Peruvian coast (88).

Application of the model to groups exploiting nonlinear and operationally unbounded environments is more difficult as it may require closure of a mating system. Wobst (176) suggests that closure in hunter-gatherer systems may become advantageous in association with high-return resource exploitation activities requiring work groups larger than those available to a single local group. He suggests large-scale game drives as a possible example of such an activity.

I argued earlier for agricultural village formation as a response to requirements for cooperation and activity coordination in subsistence activities. General ecological considerations may suggest that increasing resource density (36a, 112, 170a) associated with increased temporal and spatial predictability of resources (36a, 170a, 174) favor the development of territoriality. These factors were discussed above as favoring sedentarization. To the extent that agricultural settlement may favor territoriality and territoriality favor mating system closure, centrality of village location within a mating system may generate village population differences in the manner suggested for linear settlement systems. Territoriality may not be required to produce relatively closed mating networks in some nonlinear settlement systems. Relative closure might be expected in topographically bounded settlement systems such as those in mountain valleys. Intervalley interaction may be impeded by topographic barriers, producing relatively closed mating systems and locational advantage for central location within a valley.

Population size, however, is not the only axis of variability within most settlement systems. Sources of variability in functional size should also be considered. Here

functional size refers to the number of different kinds of activities undertaken within a settlement. A relatively homogenous distribution of activities might be expected within early agricultural settlement systems in which each village is an autonomous economic if not social unit. Some variability in type of activity may be attributable to differential resource distributions within the area of a settlement system (20), but even this in combination with differential settlement population sizes does not account for major differences in settlement functional sizes.

I suspect that initial differentiation of settlement functional size may often be related to social and only indirectly to subsistence factors. I have suggested elsewhere (81) that increasing requirements for activity coordination among population units favor the development of specialized leadership to reduce the costs of information transfer involved in coordination. Information transfer costs may be related to the number of population units whose activities are coordinated.

Activity coordination was one factor discussed above as favoring village formation. If village locational centrality favors differentially large population size and larger population size favors the development of specialized leadership, pressure for this development should be strongest in centrally located villages. Further, if "big-man" systems (129) represent one trajectory for specialized leadership development, the larger population size of central villages in addition to the interactional advantages of their location should favor larger big-man centered reciprocal exchange networks, or bigger big-men.

I have also suggested (81) that the development of specialized leadership (decision-making) positions may be associated with the development of ascribed status differences within a population. Effective coordination requires not only that decisions be made, but also that they be carried out. Decision-making positions must then be associated with a differential ability to influence the behavior of others. The use of social status differences to structure or supplement differential influence in decision-making contexts is frequently noted (147, 155, 161). Thus in Fried's (45) discussion of the evolution of political society, rank societies are differentiated from egalitarian ones partially by the development of: (*a*) specialized leadership, (*b*) ascribed social status differences, and (*c*) increase in authority.

The development of specialized leadership positions associated with ascribed status differences would produce an increase in the functional size of presumably central villages. Functional size differences might then be further increased by a number of processes potentially associated with leadership development.

Webb (164) points out, for example, that leadership personnel tend to be differentially involved in long-range trade systems. While long-range trade among egalitarian hunters and gatherers may be related to the maintenance of mating networks (176), similar exchange systems in ranked societies may be more important in acquisition of items used to symbolize and thus reinforce status differences (164). This may be especially important if status and decision-making functions are related in the manner suggested above. Some examples of elite participation in long-range trade were discussed above in conjunction with gravity models of interaction.

If higher status individuals tend to be spatially localized within a settlement system and participate differentially in long-range trade, then the organization of production of items for export in such exchange systems, the concentration of craftsmen to produce status-related items from imported as well as local materials, and related activities may lead to further increase in functional size differences within a settlement system.

Trade is not the only status-reinforcing activity that may promote increase in the functional size of certain settlements. Webster (167) has recently reviewed sacred legitimation of status differences and leadership positions in relatively complex societies. A similar function of religious activity in somewhat simpler societies might then lead to increase in the functional size of central settlements through concentration of sacred ceremonial and production of sacred architecture and paraphernalia in these settlements.

Any number of processes, including those suggested above, may contribute to the differential distribution of functional sizes in a settlement system that constitutes a simple settlement hierarchy. Many settlement systems, however, are characterized by centralization of production of a variety of goods and services. While considerations of scale economics may help explain activity agglomeration as a general phenomenon, they do not account for centralization as a pattern of markedly differential agglomeration.

Kochen & Deutsch (86) suggest that an uneven spatial distribution of demand favors centralization of the production of goods and services for reasons of increased efficiency. This is an interesting observation in light of Hudson's (69) rural location theory in which he suggests that nonuniformity of settlement spatial distributions is to be expected within developing settlement systems characterized by low settlement density, little or no competition for agricultural land, and significant variability in settlement size (see also 149).

An uneven spatial distribution of agricultural settlements and hence an uneven spatial distribution of demand should be characteristic of most developing settlement systems, leading to the question of why evidence for centralization is not more common in the archaeological record. Centralization, however, also requires initial conditions of functional diversity of production, and presumably threshold values of intensity of demand before the potential efficiency gains of centralization effect locational decision-making.

A different though complementary approach has been suggested by Törnqvist (154). He attributes centralization of certain activities to requirements of information exchange among operationally specialized components of a system. The focus is thus on the efficiency of integration of production of a variety of goods and/or services, rather than on efficiency of production of goods and/or services per se.

Törnqvist's emphasis on information exchange raises the point that a differential spatial distribution of the production of goods and services need not be the only, or even the major, factor in the development of a functional settlement hierarchy.

Effective activity coordination has been identified as the basis for the hierarchical structure of decision-making or administrative organizations (134). This organiza-

tional requirement has long been recognized as potentially important for the development of settlement hierarchies (26, 99). With admittedly notable exceptions (137, 138), however, it has received little attention in the literature. Recently Richardson (125) and especially Blanton (18) have emphasized that the movement of personnel and information in decision-making hierarchies is subject to the same transport costs as movement of personnel, goods, and services in a marketing system. Increase in the hierarchical structure of a regional decision-making organization may then favor increase in the vertical complexity of a settlement hierarchy. Taylor's (150) analysis of a series of East African societies reveals a general lack of centralized production, distribution, or redistribution in conjunction with the presence of clear settlement hierarchies which have a close relationship to decision-making hierarchies.

I suggested above that centrality of settlement location favored relatively large settlement size and initial functional differentiation. Locational considerations are important in the present context as well. A centrally located settlement is the most probable locus of productive centralization and/or highest level administrative control functions in that: (*a*) it has the highest probability of a history as the locational focus of an intersettlement interaction system, and (*b*) its location allows minimization of center-to-village movement costs. Similar movement minimization considerations favor the development of multiple centers when a settlement system is sufficiently large that movement costs effectively inhibit the interaction of distant villages with a single center. The boundary between the interaction fields of two such centers should be related to the average distance decay functions of the goods and/or services they respectively provide.

Given sufficient village-center interaction, the spatial distribution of settlements should become increasingly regular, further reducing the movement costs of interaction. Haggett (52) and Dacey (31) review alternative geometries of settlement distribution, showing that under appropriate conditions of settlement density and topographic uniformity, hexagonal distributions are the most efficient though not the only alternative model for relative settlement location.

Central Place Theory

The preceding just-so story may sound increasingly familiar to those who are acquainted with central place theory in economic geography or its applications in anthropology. Central place models provide a relatively coherent framework for the investigation of regional interaction systems as expressed in functional settlement hierarchies and their spatial distributions. Given the general availability of recent reviews of central place models by Smith (140, 142), Webber (166), and others, I see little point in repeating the process here. It would perhaps be more useful, and I hope interesting, to review some common criticisms of central place models and their application to archaeological data sets.

Quite correctly, the classical central place models of Christaller (26) and Lösch (99) are generally considered to be restricted in applicability to the analysis of retail production and marketing (13, 16, 102, 140, 170). As recently reviewed by Smith (142), theories of the development of central place systems have been closely tied

to theories of the development of retail marketing systems. Application of "central place" models in the absence of reliable data on marketing or of marketing itself has understandably been criticized (8, 140).

I have used a major portion of this review to suggest that movement minimization, activity agglomeration and centralization, functional settlement hierarchies, and regular settlement spatial distributions may occur in the absence of market institutions and, by implication, that an expanded central place theory is useful in the analysis and interpretation of such systems. Aspects of such an expanded model have been found to be useful in the analysis of archaeological settlement pattern data from a number of areas, including Mesoamerica (37, 41; 44, pp. 161–73; 54, 100), North America (188), Europe (21, 28, 61, 62, 64, 66, 96, 132), Mesopotamia (3, 78–80, 183), and Oceania (70).

Two other criticisms of central place models deal with questions of settlement functional and population size. Adams (1) and Smith (140) have criticized archaeological applications of central place models for their lack of effective measurement of settlement functional size. Archaeologists often assume that the functional size of a settlement is directly proportional to its population size.

This assumption raises the familiar problem of settlement population estimation, a question that has been reviewed recently by Schacht (131) and Ammerman et al (6). Their comments on estimation of settlement population from settlement size are of particular interest to those engaged in regional site surveys. Systematic variability in population density within a settlement hierarchy is one of the more important issues raised by their discussion. Although some studies reveal a linear relationship between population and settlement areal size (49, 108), there is little reason to believe that this relationship is a general one. Population estimation remains a difficult archaeological problem.

More work has been done on the relationship between settlement population and functional sizes. Although Crissman (29) strongly rejects settlement population as an estimator of functional size, a strong relationship between these variables appears to hold for many areas. Berry (13) reports a correlation of +0.95 between population and functional size for areas of Iowa, while Webber (166) cites studies from the states of Illinois and Washington, Australia, New Zealand, and southern Ceylon that obtained correlations of +0.70 to +0.90 between these variables.

Unfortunately, the relationship appears to be curvilinear, such that functional size per unit population decreases as population size increases (13, 48, 52, 166). Even given appropriate population estimates, the assumption of direct proportionality between population and functional sizes may then seriously overestimate the functional sizes of larger settlements, and perhaps suggest the presence of greater complexity in a settlement hierarchy than is warranted.

The problem of functional size estimation from archaeological settlement survey data is clearly difficult and as yet unresolved. This is one of the many reasons why one should view with caution the results of archaeological studies that have been unable to use direct measures of functional size.

Difficulty in identification of discontinuous settlement hierarchies has been another major source of criticism of central place models (159). Indeed, study of the

properties of continuous settlement size distributions in conjunction with the so-called "rank-size rule" has a long history. The investigation of these rank-size regularities, originally popularized by Zipf (186), has recently been brought to the attention of anthropologists by Blanton (19), Crumley (30), and Smith (139–141). Rank-size problems are sufficiently important to warrant more extended discussion.

The rank-size rule is usually considered to be an empirical generalization. The rule notes that settlement systems often have a settlement population size distribution such that when these settlements are ranked in a descending array by population size, a settlement of rank r has a population equal to $1/r$ that of the largest settlement in the system (15). This relationship is lognormally distributed so that a linear plot is produced when the relationship is graphed on full-logarithmic paper.

A number of explanations of this regularity have been advanced, and have been reviewed by Richardson (125). Zipf (187) used an effort minimization model to suggest that linear rank-size distributions are produced by the high degree of system integration among cities in economically developed countries. Rashevsky (119) related the distribution to economic opportunities and relative per capita production in a system of cities. Crumley (30) suggests an interpretation in which the degree of fit between an observed rank-size distribution and the linear model may be taken as an index of a settlement system's urbanization. Although in an earlier article Berry (12) was unable to find a relationship between linear rank-size distributions and either degree of economic development or urbanization, he now seems to feel (14) that such distributions may be characteristic of systems in the early and late stages of economic development with maximum deviation in between. In a much more general approach to the problem, Simon (135) related linear distributions to a systemic steady-state and the influence of a large number of essentially stochastic processes on the system's settlement size distribution. Such an interpretation, if supportable, would be of considerable interest to archaeologists, and I will return to it later.

While one effort has concentrated on providing explanations for linear rank-size distributions, a second has tacitly accepted them as "expecteds" and attempted to explain observed deviations from the rank-size rule. The primary type of deviation observed has been called a "primate" distribution (12) in which a full-logarithmic graphing of settlement size against settlement rank produces a markedly nonlinear, concave plot. Depending on one's point of view, large settlements are larger than expected or small settlements are smaller than expected in such cases.

Berry (14) attributes primate distributions to concentration of economic growth in the largest settlement of a system due to high availability of low-cost labor and the associated lack of incentive for decentralization. Smith (142, p. 32) is able to subsume Berry's interpretation in a more general model that relates primate distributions to " . . . the political administration of an economy in which competitive forces, necessary to a regular commercial central-place hierarchy, are minimized," a position also taken by Blanton (18). This condition is often associated with countries formerly involved in colonial empires, either as empire centers or empire

members, or in systems which are sufficiently bounded so as to inhibit the development of more than one highest order central place.

A second type of deviation in which a full-logarithmic graphing produces a markedly convex plot has been mentioned, but has received little attention in the literature. In these cases large settlements are smaller or small settlements are larger than expected. Olsson (109), citing an unpublished study by G. J. Karaska, notes that Karaska's rank-size plots for the anthracite region of Pennsylvania are very convex. Olsson suggests that this might be due to markedly differential interaction rates within and between valley settlement systems. Other examples of convex full-logarithmic distributions include those for the United States in 1790 (187); the medieval regions of Tuscany, Palermo, Florence, and Milan (128); a series of Welsh hillforts (65); and the Roman provinces of Gaul and Britain (116).

A third major area of rank-size studies has focused on resolution of the apparent contradiction between the continuous distributions of the rank-size rule and the discontinuous settlement hierarchies of most central place models. Here most work has attempted to show that clear local discontinuities may be obscured and appear as continuous if pooled and viewed from a regional or national level (15, 77, 102, 109, 139). The possible result of pooling is nicely summarized by Smith (142, p. 29): "In effect, disturbances created by any number of non-isotropic conditions—variation in population density or demand, landscape irregularities, differential distribution of transport facilities, and the like—would shift centers out of line with one another, even though they might be identical with respect to regional central place functions." Beckmann (10) and Beckmann & McPherson (11) have shown how the addition of stochastic variability to settlements at each level of a central place hierarchy tends to produce a linear rank-size distribution. Combined operation of a sufficient number of "error sources" of the sort described by Smith may be essentially random at the system level and constitute the stochastic processes postulated by Simon (135) and utilized by Beckmann to produce linear rank-size distributions.

Although the success of Beckmann's resolution of the rank-size versus central place conflict has been questioned (32, 110), his general approach appears to be the most promising. Rapoport (118) agrees that an explanation for linear rank-size distributions should be sought in the statistical structure of events effecting settlement size, while Richardson (125) suggests that both systematic and stochastic processes should be considered.

Final resolution of this problem will also have to consider inconsistencies between functional measurements of size in central place models and population measurements of size in rank-size studies. As discussed above, these variables tend to be correlated although the degree of their relationship may vary considerably.

While I agree that stochastic variability is probably a major factor in the production of linear rank-size distributions, I do not agree that the presence of a linear distribution need be indicative of a systemic steady-state, nor that nonlinearity need be indicative of system change. Most importantly, we may take it as given that the state of a system cannot be determined from a single observation in a time series.

Further, we have empirical data to demonstrate that some nonlinear, primate systems have been maintained for periods of some 450 years (142)—apparently very much in a steady state.

A general model of rank-size relationships may soon be possible. As a first step, it is necessary to recognize that variability in rank-size distributions does not range simply from primate to linear log-normal, but from primate (concave) through linear to convex. I would like to suggest that various only vaguely recognized problems of scale may contribute no little confusion to the rank-size problem.

D. R. Vining (158) has suggested a series of processes including decline in a system's growth rate that may have produced some convexity in rank-size distributions for the United States over the last 20 years. Here I would like to suggest two general conditions favoring convex distributions that do not assume system growth. First, convex distributions should normally appear when the size distribution of a settlement system actually approaches the discontinuous hierarchy posited by central place theory, at least in cases with multiple highest order central places. Presumably this should occur in the absence of both processes leading to primacy and of stochastic effects of sufficient magnitude to alter the settlement size distribution. In general, the larger the region studied, the greater should be the probability of operation of stochastic processes due to variability in population density, demand, topography, and so on.

Second, convex rank-size distributions may appear when a series of adjacent systems of roughly equivalent scale and characterized by limited intersystem interaction are pooled in the same analysis. This situation might be expected in modern areas with complex topography and poor transportation nets, such as the Pennsylvania region mentioned earlier. Given the generally smaller scale of social and economic systems in the past, convex distributions should be more common in archaeological than modern data. A convex rank-size distribution should then alert the researcher to the possibility that relatively autonomous settlement systems are being combined in analysis—a possibility that need not be obvious. As noted above, concave rank-size distributions appear to be related to the political administration of an economy and minimization of competition. Problems in system boundary definition, however, may produce essentially artificial primate distributions in both archaeological and modern data sets. Boundary problems might be of two sorts: 1. the region actually studied may be significantly smaller than that occupied by the effective settlement system of interest, and 2. a significant proportion of the population and functional size of the largest settlement in a study region may be related to that settlement's articulation with a larger scale system (19, 157).

The first problem is probably restricted to archaeological data sets drawn from often arbitrarily defined survey regions. The second problem may be of wider interest. Smith (142) cites the primate curves for Japan and England as notable exceptions to the norm in which rank-size curves for nations with "fully developed" economies are generally linear. The fact that these island nations are significant food importers (179) suggests that the effective hinterlands of their major cities extend well beyond their national boundaries. Similarly, the primate curves cited by Smith (142) as characteristic of nations that are either former members or centers of

empires may result in part from the differential involvement of their capitals in supranational settlement systems.

Little further time need be spent on linear rank-size distributions. Given Simon's (135) probability formulation and Beckmann's (10) demonstration that such a model is consistent with a functional hierarchy of central places, the stochastic interpretation of linear rank-size distributions would seem acceptable. Such a system would be characterized by the absence of directional processes of sufficient magnitude to override the stochastic effects of variability in population density, demand, etc. Presence of a linear relationship would also suggest that operationally effective settlement system boundaries have been identified.

If this discussion has any contribution to make to rank-size studies, it probably lies in more explicit consideration of the potential effects of scale errors on such distributions. Recognition of these effects should be particularly important in the analysis of archaeological data.

Let me illustrate this point with comments on four rank-size plots of settlement data spanning some 800 years of development on a major alluvial plain in Southwestern Iran. The area of this plain is some 2280 square kilometers (79).

Figure 2a shows the distribution for settlements of the Terminal Susa A period (ca 3900 B.C.) just after the apparent collapse of a large chiefdom in the area. The settlement pattern reveals four rather isolated settlement enclaves suggesting the presence of four relatively autonomous sociopolitical units. Note that Figure 2a is markedly convex, the predicted result of analytical pooling of separate settlement systems.

Figure 2b illustrates the distribution for the Early Uruk period (ca 3700 B.C.) during which state formation seems to have occurred in this area. While the western portion of the plain appears to have been unified under a single administrative hierarchy, the eastern portion may have remained relatively autonomous. Note that the rank-size plot shows an increase in linearity, though it is still quite convex in the lower settlement size range.

Figure 2c illustrates the distribution for the Middle Uruk period (ca 3400 B.C.) during which state level controls seem to have been extended to cover the entire plain. The plot is linear and probably reflects not only the operation of various stochastic processes on the settlement size distribution, but also a close fit between the scale of the region surveyed and the spatial scale of the economic system operating at that time.

Figure 2d illustrates the distribution for the Late Uruk period (ca 3200 B.C.). Note that the plot is noticeably primate. Wright (182) has suggested the resurgence of a long range trade system in this area at a slightly late date. New data (82, 168) suggests that this process effectively began during the Late Uruk. To some extent then, the primacy of the Late Uruk rank-size curve may reflect the differential participation of the larger settlements in this area in a larger scale settlement system —in this case one involved in a major new interregional exchange network.

The four plots discussed above illustrates a final rank-size problem. Note the rapid falloff in each plot below a settlement size of about one hectare. This deviation from the "expected" number of increasingly smaller settlements has been called a problem of "lower-limb relationships" by Haggett (52). These deviations probably indi-

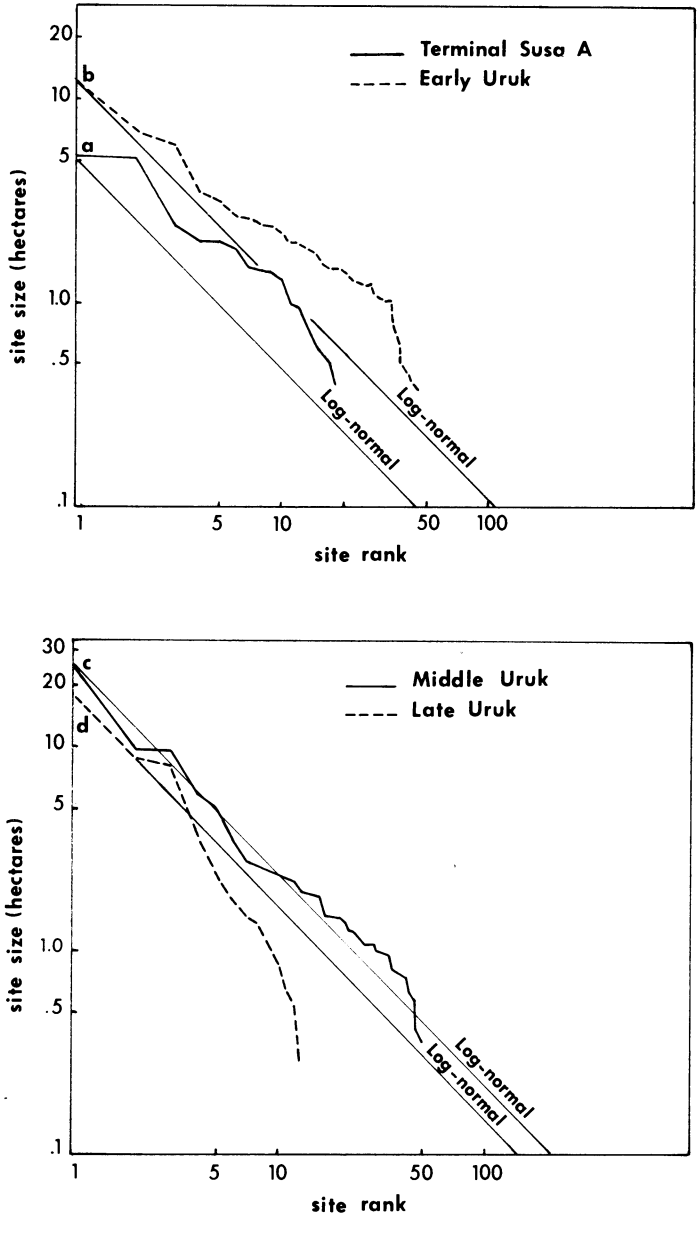

Figure 2 Rank-size distributions of settlements on the Susiana Plain of Southwestern Iran: a. Terminal Susa A, b. Early Uruk, c. Middle Uruk, d. Late Uruk.

cate effective threshold values for viable settlement size within individual settlement systems.

I would conclude this section with the suggestion that not only may the concept of the rank-size distribution be of considerable utility to archaeologists, but also that archaeologists are in an unusually favorable position to contribute to the resolution of long-standing rank-size problems. They control a scarce and valuable resource: long-term, regional scale settlement pattern data.

CONCLUSIONS

Even though space limitations have precluded more than scratching the surface of the problems and approaches involved in the analysis of regional interaction systems, it should be clear by now that such analysis is a complex affair. I would like, therefore, to make some cautionary comments on the general utility of central place and other locational models to archaeology.

I agree with Webber (165) that most models of locational behavior are essentially unverifiable in that for the sake of generality they involve assumptions which are untestable or which cannot be expected to be met under real world conditions. Utility and testability, however, are not necessarily coterminous. Most authors agree that these models provide context within which the operation of real world processes may be understood.

It is important to follow Webber (165) in making a distinction too often ignored by archaeologists between understanding and prediction. Prediction in the statistical sense is often equated with understanding or more generally with explanation. Accounting for even 100 percent of the variance of a variable and to thus be in a position to predict its values (at least in the past) need not imply understanding of the causal processes involved. Archaeologists are becoming increasingly adept at the statistical explanation of variability and yet have made only little progress in understanding process. Use of most locational models will not promote prediction. Given suitable caution, however, use of these models may well promote understanding.

Theoretical innovations are required which will integrate understanding and prediction in the same formulation. These models will have to depart radically from the determinist structure of most locational formulations in which given a series of behavioral assumptions and a set of initial conditions, the outcome of the model is set and immutable. The work of Dacey (33), Hägerstrand (51), and Morrill (106, 107), among others, is encouraging in this regard in that they have attempted to incorporate stochastic variability within classical location and interaction models.

Yet enthusiasm for stochastic processes may go too far. The last 10 years have seen an increase in entropy maximization explanations derived from information theory and exemplified here by Simon's work on rank-size regularities. If the most probable state of a variable or system is equated with maximum entropy, then behavioral patterns as reflected in spatial regularities are viewed as most-probable steady states resulting from purely random processes (17). These approaches encourage taking regularity as given and shifting the emphasis of explanation to

deviations. At least in archaeology we may profitably continue to try to understand the factors producing the probability distributions that make most-probable states most probable.

Even if we succeed in formulating, or more probably borrowing, general theory which facilitates both understanding and prediction, a final consideration suggests caution in its application. Speth and I (145) have recently noted that a wide variety of different behavioral patterns may produce similar artifact distributions on paleolithic living floors. Hodder & Orton (65) make the same observation for archaeological data in general.

Smith (142) points out that patterned spatial distributions of hierarchically organized settlements are very common in the world, and even a cursory review of the locational literature reveals the great variability in locational systems and the conditions under which they may develop. Selection among alternative processes or sets of processes to account for observed patterning is a matter of appropriate formulation and evaluation of test implications. Given the problems of equifinality, however, it is worthwhile to reiterate the old axiom that successful support of a hypothesis is best viewed as simply failure to reject it.

With these thoughts in mind, I would still note that the state of behavioral theory in archaeology is such that a coherent model of certain types of behavior need not be very powerful to be useful. The simple concept of movement minimization, for example, has been subjected to rather extensive use in this review. I feel relatively confident in asserting that use of many of the concepts developed in other fields for the investigation of regional interaction systems has and will contribute significantly to our understanding of past human behavior.

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